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REA

EXPERIENCE WITH DYNAMIC MATERIAL CONTROL SUBSYSTEMS*

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ABSTRACT

Operation of a Dynamic Material Control (DYMAC) prototype system has yielded some useful information for installing the final system. We discovered a bias between two methods for measuring filtrates. Evaluation of a unit process dynamic balance brought to light an operating procedure that weakens the accountability goals of the DYMAC system. We were able to correct both situations for the final system and learned that we must regularly monitor the system once it is operational for similar discrepancies.

INTRODUCTION

DYMAC--the in-plant material control system being developed at the Los Alamos Scientific Laboratory (LASL)--combines nondestructive assay (NDA) instrumentation, advanced accountability techniques, and computer technology to provide dynamic material control for the new LASL plutonium processing facility presently nearing completion.

A prototype DYMAC system was tested at the existing LASL plutonium facility over a 3-month period. Operation concluded on March 31, 1977 to allow DYMAC staff to concentrate on installing the DYMAC system in the new facility. The experience gained from operating the prototype system has provided valuable information for a smooth implementation and startup of the final DYMAC system which begins operation at the new facility in the fall of 1977. Two years from then we expect DYMAC to be fully operational.

ACCOUNTABILITY

The DYMAC system makes use of the unit process accounting area, (unit process, in short) as the basis of in-plant material control.[1] We have defined unit process as a unique physical location around which a dynamic balance is drawn on a batch basis. Unit process selection requires careful consideration of several criteria: Input and output to the unit process must be mea-

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sured with a reasonable amount of accuracy. One must take into consideration the amount of material that comprises a batch and the batch residence time within a unit process. Within the constraints of process logic, the parameters must be balanced to maximize the sensitivity of the unit process dynamic balance.

We speak of dynamic balance because processing does not stop for cleanout between batches. As each batch is processed, we measure feed materials, product output, and recycle and scrap materials. The expected value of the dynamic balance is nonzero because small amounts of process residue are allowed to accumulate within the unit process. We assume that these residue quantities are small and consistent from batch to batch. Advanced accountability techniques, such as cumulative sums (which are discussed later in the paper), are used to determine the value of the dynamic balance.

PLUTONIUM OXIDE PRODUCTION

The DYMAC prototype system was set up to follow an ongoing process at the existing plutonium facility: the conversion of plutonium metal to oxide. We defined four unit processes that make up this process: receiving, cutting, dissolution, and screening (see flow diagram in Fig. 1).

The metal ingot is the input to the receiving unit process; it is entered at the shipper's value. The ingot is unpackaged and the surface oxide scraped off. The cleaned metal ingot, plutonium oxide, and contaminated packaging material are the measured output. The dynamic balance is calculated for this unit process which is then used to determine the difference between shipper and receiver values.

The clean metal ingot is the input to the cutting unit process where it is quartered. The quarters, metal sawdust, and cutting process solids are the measured output. In this unit process, the value of the batch dynamic balance represents the accumulation of small amounts of cutting residues within the glovebox. This accumulation is assigned to the material-in-process (MIP) account for the cutting unit process.

The metal quarters and sawings are the feed material for the dissolution unit process. The pieces are separately dissolved with nitric acid and then the nitrate solutions are blended. The plutonium in the blend solution is purified by a peroxide precipitation, followed by redissolution and an oxalate precipitation. The plutonium oxalate is then calcined to produce plutonium oxide which is the output for the dissolution unit process. Undissolved metal is recycled on a measured basis. Other output from the unit process--residues, peroxide and oxalate filtrates--is measured and sent to a recovery process. The value of the dynamic balance for each batch is calculated and assigned to the MIP account for the dissolution unit process.

In the screening unit process, the input oxide is screened and blended before being packaged as the final product. A dynamic balance is drawn using an NDA determination of the plutonium oxide quantity. This NDA value is later replaced by the more accurate chemical assay results when they become available.

NDA MEASUREMENTS

The DYMAC prototype made extensive use of NDA techniques to draw unit process dynamic balances in as near a real-time sense as possible. Because most input and output was either plutonium metal or oxide, balances were widely used. Solid residues removed from the plutonium oxide process were measured by the segmented gamma scanner. An on-line thermal neutron coincidence counter made the initial assay of the cans of product plutonium oxide.

We had a most enlightening measurement experience with the solution assay instrument, a high resolution Ge(Li) detector. Its function in the plutonium oxide process is to measure plutonium concentration in peroxide and oxalate filtrate solutions. Large tanks of filtrates are weighed by a load cell device to determine solution weight. A sample containing approximately 25 mℓ of solution is drawn from the tank and an exact sample weight is determined using an electronic digital balance. The sample is then analyzed using the solution assay instrument to determine mass plutonium in the sample.

This is the standard sequence of measurements used to calculate the mass of plutonium in the filtrate tank. Prior experience[2] had indicated that accuracies of approximately 5% relative standard deviation could be expected from the solution assay instrument for filtrate measurements. We compared a number of solution assay determinations with results obtained by radiochemistry. The comparison indicated a statistically significant bias between the two measurement methods for the peroxide filtrates: results of the solution assay instrument were approximately a factor of 2 lower than those obtained by radiochemistry. This discovery prompted us to investigate the difference between the two methods. The extremely high ratio of americium to plutonium in the peroxide filtrates resulted in pulse pile-up from the 208-keV americium peak which interfered with the gamma-ray assay of the 414-keV ^{239}Pu peak. We eliminated the bias by adding an algorithm to the solution assay instrument software which compensates for this interference.

This experience has demonstrated that all measurement systems must be thoroughly tested using actual process material. Changes in process conditions may adversely affect measurement accuracies. A continuing program is necessary to verify measurement accuracies by occasional comparison with independent measurement systems.

COMPUTER SYSTEM

The DYMAC prototype system demonstrated that a dynamic inventory of material can be maintained as it undergoes processing. A terminal was set up in the plutonium oxide production area. Each time an operator completed a step he entered that information at the terminal which sent it to the NOVA 840 computer to update the inventory.

DYMAC software has been designed to simplify the entry of information into the data base. When an operator completes a processing step, he must make a transaction. A transaction is a general vehicle for updating the data base. A *process transaction* is modeled on a particular process. Much of the information remains unchanged each time that a process transaction is used (e.g., account number, project, item description). For the prototype we designed a process transaction to parallel the steps in the plutonium oxide process. From the terminal display the operator selects the processing step that he just finished. Through a series of prompts he supplies a few pieces of information related to that step (e.g., lot identification, material type, bulk weight). The data base supplies the rest of the information to complete the transaction.

Process transactions make it easier and quicker to complete a transaction. They also have a built-in diagnostic capability which reduces input errors. For example, data record fields are defined to be of a specific character type, thus data entered into a field can be checked for correct character type. Before the transaction is sent to update the data base, the operator has a last chance to alter what he has entered: the entire transaction is displayed for his verification and is only sent when he is satisfied that all the information is correct.

The prototype computer system and software are similar to what is being implemented in the new plutonium facility. The DYMAC system will make the entire inventory of the new facility available at all times. As material moves through the facility, the system will create, alter, or delete the appropriate record in the inventory and record completed transactions in a history file as was done in the prototype system for the plutonium oxide process.

The DYMAC system makes much information available to operators through on-line terminals, thus minimizing the number of printed reports. Through the terminal system an operator can obtain accountability and process information almost instantaneously. He can request on-line reports such as listings of material by location with current total mass plutonium and criticality limits displayed. Reports of transaction activity are also immediately available. Process supervisors will be furnished with a printed listing of their inventory holdings each morning to encourage quick daily inventory checks. Other printed reports which require sorted data will be available to process supervisors upon request.

MEASUREMENT CONTROL PROGRAM

A measurement control program ensures accuracy of response and consistent measurement precision for the counting instruments used in the prototype DYMAC system. The program currently makes use of two control parameters. The t-distribution is the control parameter for accuracy of response and the χ^2-distribution is for precision. Both parameters are controlled by warning limits at the 95% confidence level and action limits at the 99% confidence level. Examples of control charts for the t- and χ^2-parameters are shown in Fig. 2. These charts were generated using data obtained from the segmented gamma scanner which measures solid waste material.

The measurement control program is an essential feature of the DYMAC program since it provides assurance that measuring devices are functioning properly. The measurement control program for the prototype system was not administered by the NOVA 840 computer; however, in the final DYMAC system at the new plutonium facility, the computer will monitor and execute the measurement control program in real time. The program will also be expanded to include all measurement devices and not just counting instruments.

DATA EVALUATION

The most important task of DYMAC is to evaluate the data obtained by the accounting system. DYMAC will make use of cumulative sum (cusum) techniques to evaluate unit process dynamic balances. This type of evaluation was not included in the prototype; however, the system did provide the necessary information to allow off-line computations.

Figure 3 shows a cusum chart for the MIP account associated with the cutting unit process. The behavior of the chart is somewhat erratic. We include it here to demonstrate a lesson gained from operating experience with the DYMAC prototype. The erratic behavior is due, at least in part, to scrap material buildup from several batches on an unmeasured basis, which has been credited to a single batch. Dynamic balancing is effective only if batch dynamic balances are relatively small and consistent. This erratic situation demonstrates the need to train operating personnel to meet the accountability standards of the DYMAC program. Operators will undergo a formal training program for DYMAC users before they gain access to the system at the new facility.

The DYMAC computer system will construct cusum charts for each unit process in near real-time. Each cusum chart will be evaluated on-line using the V-mask techniques discussed by Cobb et al.,[3] and the value of the dynamic balance will be compared with predetermined control levels. When either a single batch or the cumulative sum of batch balances exceeds the control level, the computer system will alert the person in charge who will determine why the value is above the control level. Normally a thorough cleanout of the unit process area will remedy the situation.

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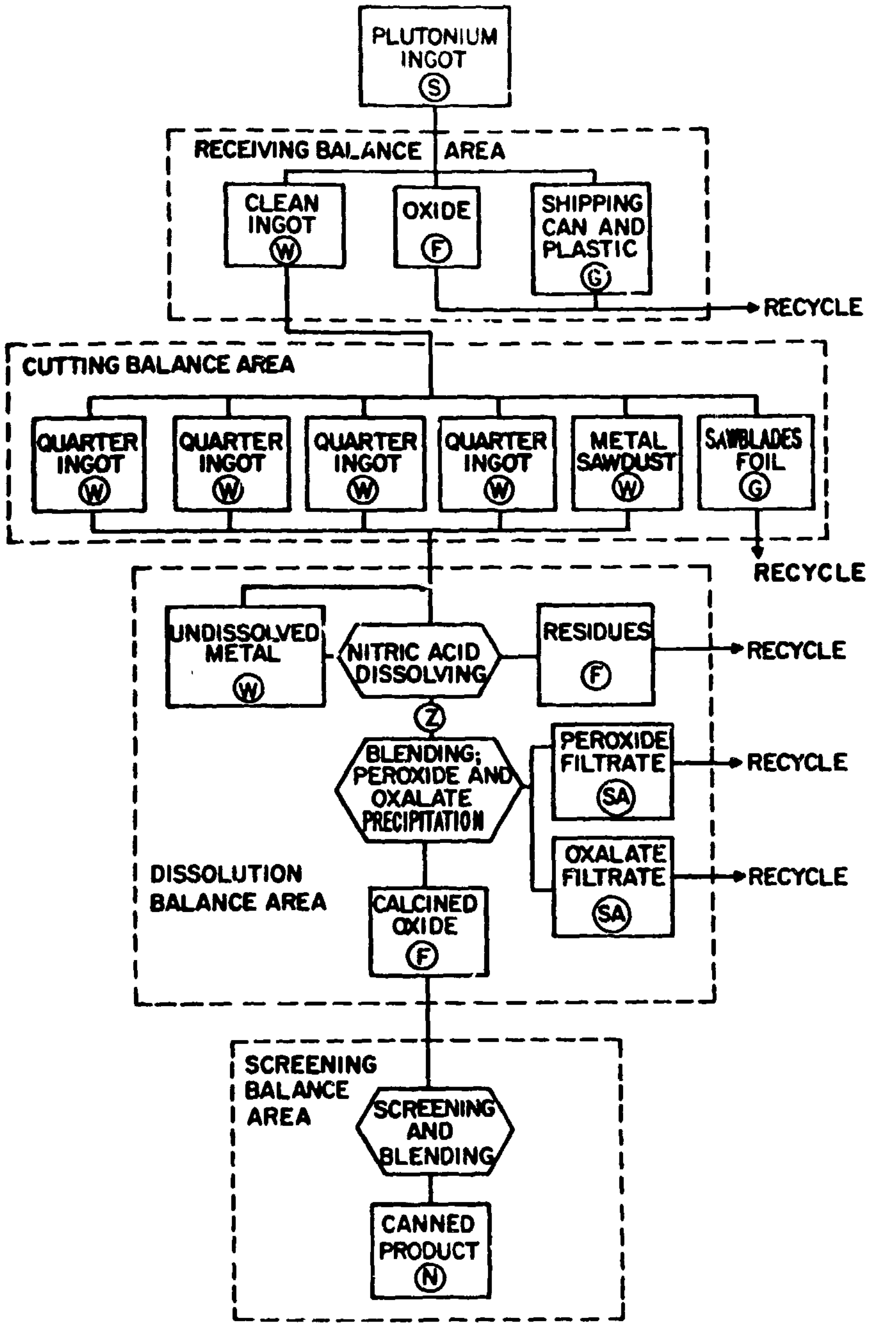
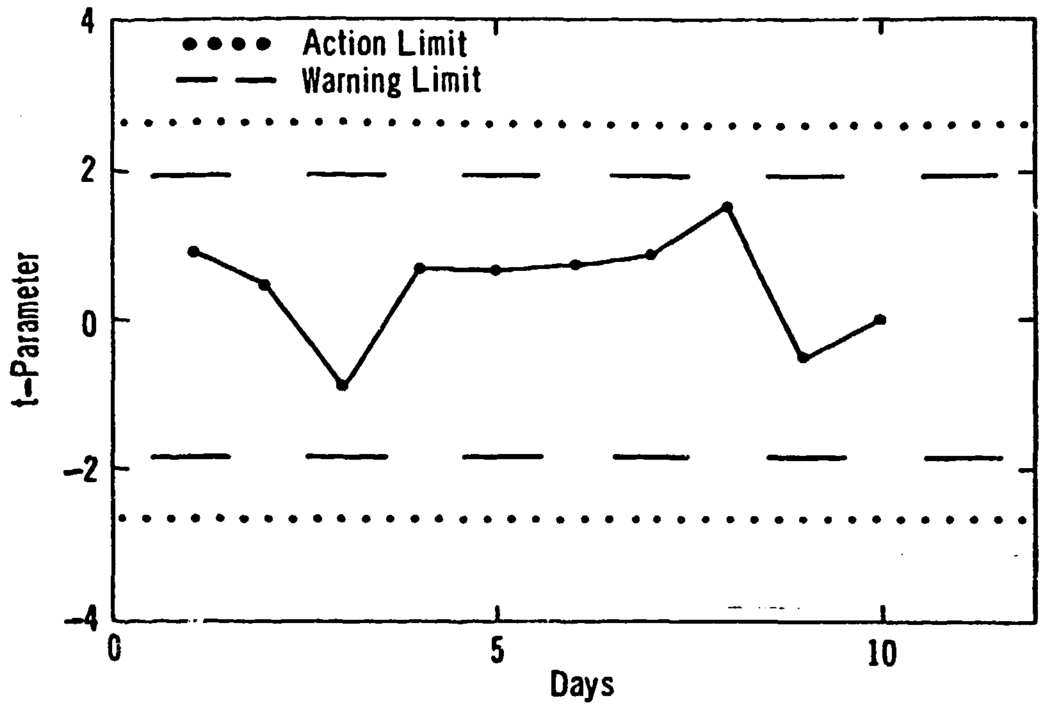
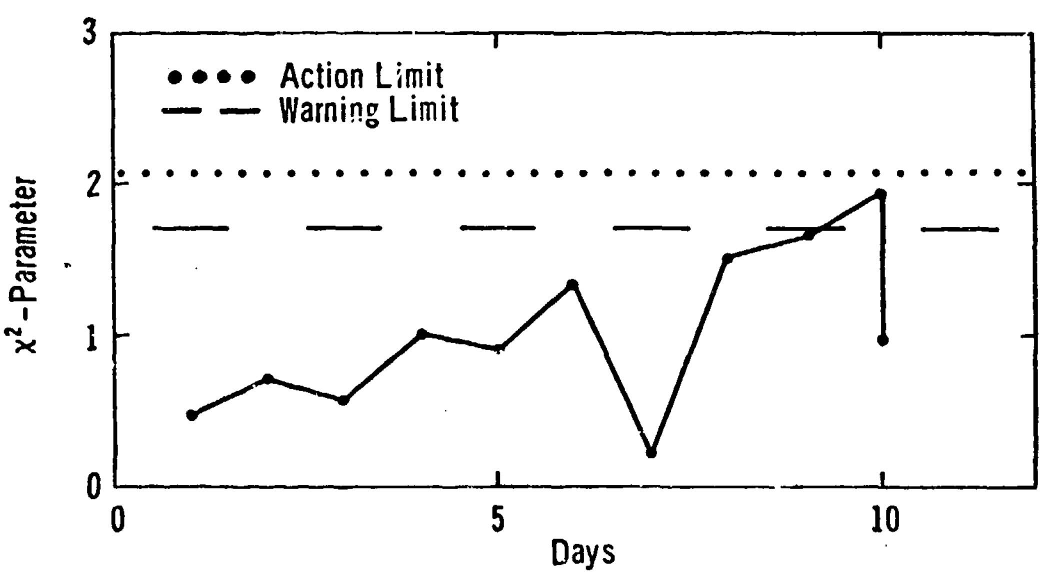


S	SS VALUE AND % PURITY AT SHIPPER'S VALUE
W	BULK WEIGHT MEASUREMENT X % PURITY = SS VALUE
F	BULK WEIGHT MEASUREMENT X % PURITY X OXIDE FACTOR = SS VALUE
G	SEGMENTED GAMMA SCAN MEASUREMENT OF ^{239}Pu MASS
SA	SOLUTION ASSAY MEASUREMENT OF ^{239}Pu MASS
N	NEUTRON COINCIDENCE COUNT OF ^{240}Pu MASS
Z	RATIO OF VOLUME TO BE BLENDED TO THE INITIAL VOLUME

Fig. 1. Flow diagram of FFTF oxide production process showing NDA measurement points and material balance areas.



a. t control chart.



b. χ^2 control chart.

Fig. 2. Control charts for t and χ^2.

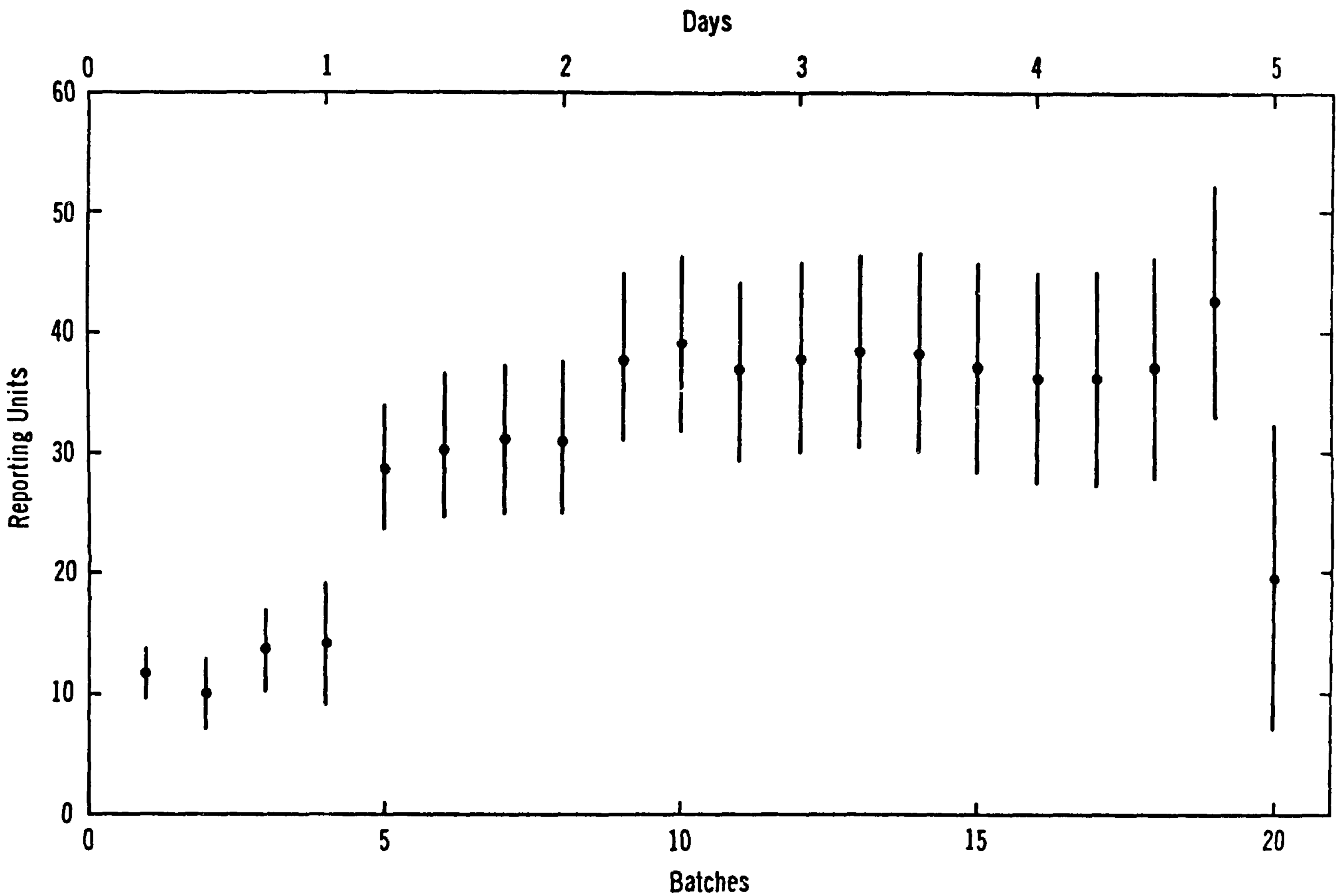


Fig. 3. Cumulative sum chart for cutting unit process area.